

Bedform Parameterization and Object Detection from Sonar Data- Application of Finger Print Algorithms

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LONG-TERM GOALS

The long-range goals of this research are to improve our ability to characterize the seabed geometry and texture in energetic inner-shelf/bay mouth settings composed of heterogeneous sedimentary material and possessed of dynamic seabed ripples. Our purpose is to improve our understanding of bedform dynamics and spatio-temporal length scales and defect densities through the application of a recently developed finger print algorithm technique (Skarke and Trembanis, 2011) in the vicinity of manmade seabed objects and dynamic natural ripples on the inner shelf utilizing high-resolution swath sonar collected by an AUV and from surface vessel sonars in energetic coastal settings with application to critical military operations such as mine countermeasures.

OBJECTIVES

The objectives of this project is a sonar based (platform independent) bedform parameterization and acoustic object detection system applicable to the whole spectrum of coastal and estuarine settings.

The following are the specific objectives of this research:

1. Conduct a local field experiment at the existing Redbird Reef, DE artificial dump (objects include tires, military vehicles, shipwrecks, and over 900 former NYC subway cars) to measure, over the extent of the field site, the object scour evolution, morphodynamic behavior, sediment texture, and bedform characterization through remote sensing techniques.

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2. Extend and apply recently developed finger print algorithm techniques (Skarke and Trembanis, 2011) for ripple parameterization and object detection using AUV, ship, and rotary sonar derived backscatter and bathymetry data.
3. Extend the ARA system developed by UNH into energetic and heterogeneous shelf settings and in particular the abundance of variously sized manmade objects will provide a unique testing set for ARA remote classification techniques

APPROACH

Our approach is to obtain a suite of field observations by performing high-resolution seafloor mapping over the extent of a natural seabed system approximately 1-2 km's on a side including the areas with dynamic ripple bedforms and manmade structures. Our approach is to gather (1) the optical and acoustic backscatter properties of surface sediment layers from an autonomous underwater platform and from surface vessel multibeam echosounder sonar, (2) the small scale (sub-meter) bathymetry and morphology from a small maneuverable AUV platform, and (3) further develop and test a remote acoustic segmentation and classification system (ARA) for bathymetry and backscatter data collected by the AUV. We will also deploy and maintain a bottom moored instrument package with ADCP (waves and current) and rotary sonar (2D ripple) for time-series measurements of hydrodynamics and small scale bedform dynamics (*sensu* Skarke and Trembanis, 2011). The fusion of field data (hydrodynamics and morphology) with the ARA remote acoustic model can be used to improve our understanding of the response of the seabed to mean and oscillatory flows (tidal and wave driven respectively) and the interpretation of acoustic imagery for surface textural properties of surficial sediments on the seabed in other settings.

WORK COMPLETED

Finger print algorithm development

An extensive finger print ripple code tutorial and code enhancement has been completed allowing new users to quickly come up to speed on the work flow and algorithm outputs from the finger print code (Figure 1) for use in a variety of sonar image formats (i.e. side-scan mosaic, rotary sonar images, multibeam backscatter or DEM surface).

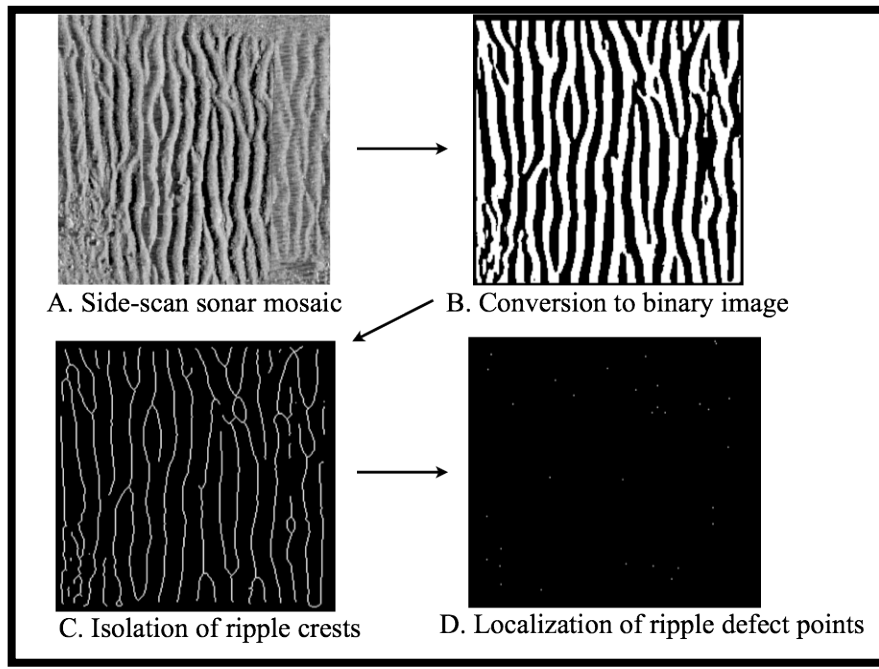


Figure 1. Stages of the finger print algorithm analysis of ripples in high-resolution side-scan sonar data. 900 kHz side-scan sonar collected from the UD AUV during AUV Hydro Bootcamp 2012.

Field Campaign Preparations

The research team has conducted several in person project planning meetings and remote meeting sessions in order to prepare the cruise and field deployment plans. A detailed field survey campaign was developed and submitted for ONR approval (received September 2012). With approval in place an upcoming cruise and instrument deployment is planned for October and December 2012.

Bottom mount Deployment and AUV/ROV Component

Our objectives are to repeat the previous map an $\sim 1 \times 0.5$ km patch with the AUV, inspect and confirm our targeted mooring site with an ROV and then deploy an instrumented bottom mount. Furthermore through the deployment of an instrumented bottom mount we will seek to measure the nearbed turbulence, wave and current hydrodynamics and the temporal evolution of ripples in the coarse wave orbital ripple domain on the seabed.

Bottom mount configuration

An instrumented bottom mount is being readied for deployment in October with retrieval planned for December 2012. The bottom mount consists of the following instrumentation

- *600 kHz upward looking ADCP with wave and current profiling capability
- *2.25 MHz Imagenex 881 rotary fanbeam sonar for timer-series measurements of bedform planview geometry
- *2 mHz Aquadopp HR profiler for nearbed turbulence in the BBL

The following sampling configuration is planned for the deployment

RDI Workhorse Sentinel ADCP- configured to measure profile of currents every 30 min and a 5 minute wave burst every hour

Imagenex- 2 scans every hour set to a range of 4 m and 9 m respectively

Aquadopp- burst sampling every hour for 5 min in HR configuration (8 Hz)

Site Location

We have selected to deploy at the same site as in our Aug-Sep ADCP deployment (DE EPSCoR project) within the megarippled gravelly fine sand facies (a Sorted Bedform feature) in the vicinity of the Redbird reef structures (Figure 2).

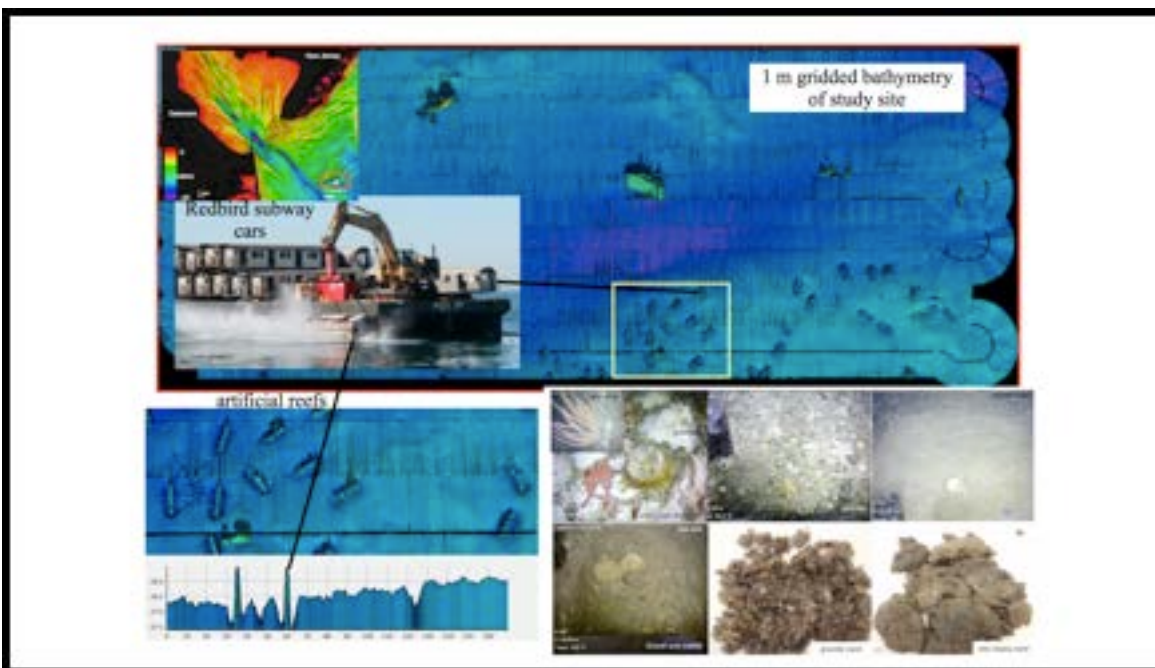


Figure 2. Field survey site location

Ship Multibeam Component

A 1.0 x 0.5 km area will be surveyed in detail using a Reson 7125 SV2 system deployed on RV *Hugh Sharp*. The 7125 system can provide bathymetry and seabed imagery/backscatter. The survey will be repeated at least twice in order to assess the impact of sonar system configuration on the ability of the fingerprint algorithm to detect seabed bedform features. The first survey will optimize the system configuration for bathymetric resolution whereas the second survey will focus on obtaining the best possible backscatter data. AUV and other instrumentation deployments will be done during daylight hours, all multibeam mapping will be conducted overnight during the field trials.

Survey Design

The seabed features of interest have spatial wavelengths on the order of 0.6 to 1.2 m with amplitudes of 0.10 to 0.15 m (0.20 to 0.30 m, peak to trough). The 400 kHz mode of operation for the Reson 7125 yields the highest angular resolution with transmit/receive beamwidths of 1.0° and 0.5°, respectively.

Given an average depth of 27 m, this yields spatial resolution on the order of 0.5 m x 0.25 m (TX and RX) at nadir, this will worsen with beam angle. In 400 kHz mode, the 7125 system forms 512 receiver beams. These will be spaced in an equi-distant manner across the swath and the vessel speed will be adjusted to match the ping rate such that the along-track sounding density matches the across track density afforded by the 512 receiver beams. Initial calculations using an angular sector of 120° and a ping rate of 15 Hz indicates that a vessel speed of 5 kts should be used. At this speed, the main survey area will take 2-3 hours to survey, including time spent turning between survey lines.

Testing operations will be done during the transit and initial daytime operations to ensure the system's ability to resolve the desired features. Line spacing can be adjusted accordingly based on findings from the testing operations. The 7125 system's seabed imagery data can be processed to provide a seafloor backscattering strength mosaic, normalized to an incidence angle of ~45°. The angular response of the seafloor over a range of incidence angles can be used to perform ARA in an attempt to characterize the nature of the seafloor.

Sonar system readiness

As part of our field project readiness effort, members of the project team planned and hosted a major development/training event focused on best practices techniques for hydrographic mapping from an AUV. In August, more than 20 people came to New Hampshire for the AUV Bootcamp, a week-long annual workshop where scientists and professionals from around the world gather to develop and improve AUV methods. This years event called "AUV Hydrographic Bootcamp" was held in New Hampshire in August, 2012 and involved a broad group of participants including several from the Naval Oceanographic Office.



Figure 3. The 2012 AUV Hydrographic Bootcamp included important field readiness testing of the UD AUV system.

AUV Bootcamp allowed us to conduct field readiness tests of the AUV we will be using in our upcoming cruise and also provided useful sonar images of ripples (Figure 1) that we were able to use

to further test our finger print algorithm and the recently developed MPAA (most probable angle algorithm) technique for processing phase measuring bathymetric sonar (Schmidt, Weber, and Trembanis, 2012) <http://ccom.unh.edu/auv-bootcamp-2012>

R/V Sharp new Reson 7125: In addition to the efforts involved in reading the AUV for the upcoming project field campaign, members of the project team have been directly involved with the final integration and system testing efforts related to the new Reson 7125 multibeam echosounder aboard the R/V Sharp. This system is undergoing system installation and testing and will be utilized by the project team to provide additional data coverage of the field site and serve as a cross-check to the AUV derived mapping data.

RESULTS

An efficient and new computational capability for implementing finger print algorithms for bedform parameterization has been developed and tested with existing and recent sonar data identical to that which will be collected in the upcoming field campaign. Furthermore, a robust new approach for consistent and rigorous treatment of dense and inherently noisy phase measuring bathymetric sonar data has been developed and tested with existing and recent shake down surveys (Schmidt, Weber, and Trembanis 2012) and is part of our new processing pipeline for the data that will be collected in our field campaign. These two software components comprise new capabilities that are being utilized in this project.

IMPACT/APPLICATIONS

This project will enhance existing ONR sponsored Mine Burial and Mine Countermeasure research by incorporating additional detailed field observations utilizing sonar systems from both a surface ship and a small portable AUV. The application of the recently developed finger print algorithm technique for bedform parameterization (Skarke and Trembanis, 2011) to bedform characterization provides a novel tool for object detection with impact to mine countermeasures. This project also builds upon and extends previously sponsored ONR efforts (Mayer and Trembanis, 2008) to develop remote acoustic techniques (ARA- angular response analysis) for seafloor segmentation and classification. This project will also provide meaningful additional acoustic data, which will then be used by Trembanis and Mayer to specifically address the continued development of ARA techniques.

RELATED PROJECTS

This project builds off of our previous project ONR Award Number N00014-07-1-0666

Mayer and Trembanis 2010. Following successful AUV field ripple surveys in 2009 in the vicinity of the Martha's Vineyard Coastal Observatory we developed experience and protocols for both field operations and data analysis workflows to handle the integration and processing of the dense sonar data from the 500 kHz phase measuring bathymetric sonar. Both that project and our ongoing work in the existing grant have allowed us to further refine our ability to work with phase measuring bathymetric sonar and both have and will provide additional data for us to continue testing and expanding the frequency domain of the ARA (angular range analysis) work that will inform this and other site studies.

Another related project of note DE EPSCoR/DE Sea Grant. A recent Delaware EPSCoR project by PIs Luther, Trembanis, and Lipphardt provided the opportunity for us deploy our ADCP at the Redbird site for a 4 week period gathering valuable background data of currents, waves, and salinity and temperature structure in the water column over the period from August 15-Sept 14, 2012. These data allow us to compare the *in situ* site measurements to both surface CODAR currents (Lipphardt) and to the nearest NDBC buoy #44009, which will allow us to compare the conditions at the site to the long-term record from the buoy. This initial deployment also allowed us to test the deployment configuration of the exact identical bottom mooring that we will be using in our Oct-Dec 2012 deployment.

Benthic Hardbottom Mapping in DE Bay- NOAA Sea Grant (Trembanis- Co-PI). This project first introduced us to the Redbird reef site offshore of Delaware Bay and allowed us to conduct reconnaissance surveys of the seabed in this area between 2008-2011. This project resulted in several publications and a PhD student project (N. Raineault completed Spring 2012).

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